Evaluation of Rainfall-Runoff Trends in the Upper Colorado River Basin Phase II

Project Update for BBASC

March 1, 2019

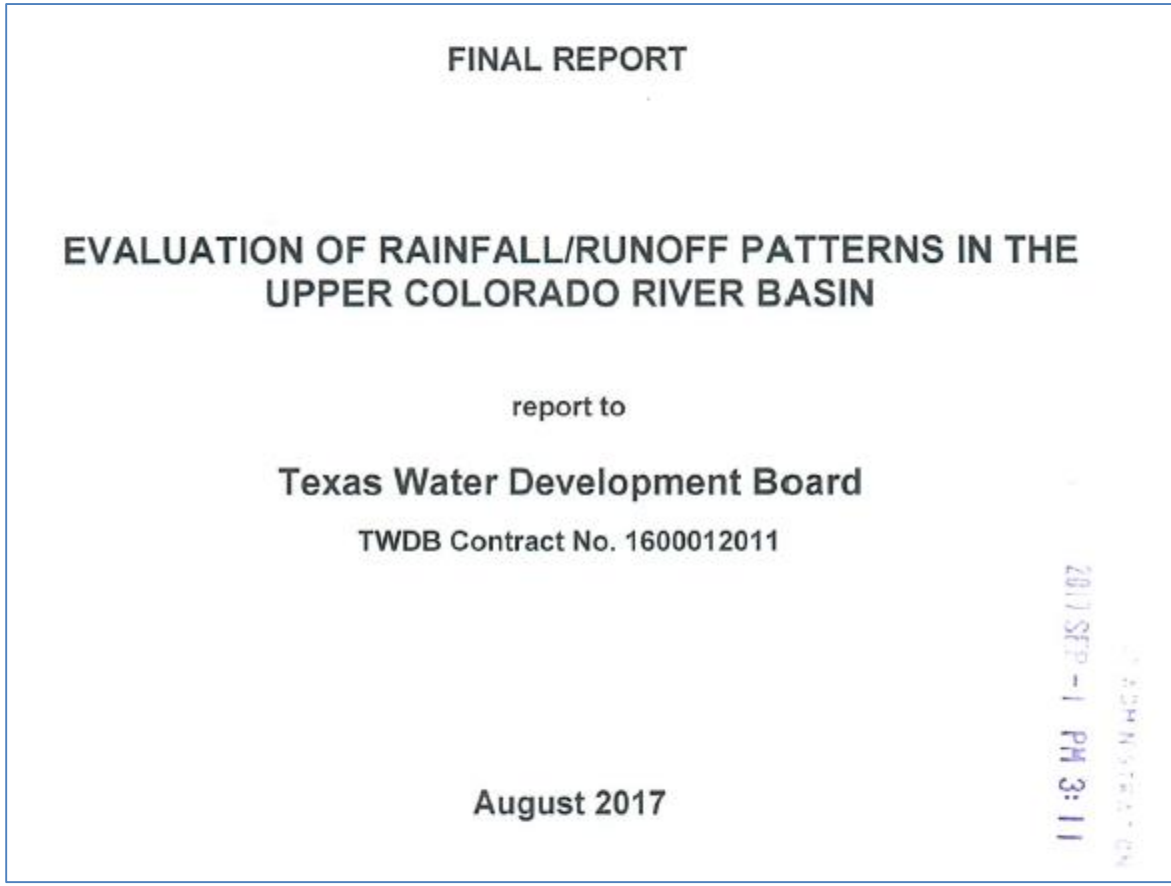
Project Funded Through TWDB Contract Number 1800012283

Phase I Review & Objectives

- Phase I
  - Confirmed streamflow appears to be Decreasing
  - Precipitation is steady or slightly increasing
  - Most decreases attributable to permitted water rights and upstream permitted reservoirs
  - *“activities not accounted for in the flow naturalization process could have impacted observed flows to some degree over the period of record.”*

- Likely Causes:
  - Noxious Brush
  - Small/Exempt Impoundments
  - Groundwater use and water level declines
  - Average Temperature and Drought Conditions

Phase II Investigation


FINAL REPORT

EVALUATION OF RAINFALL/RUNOFF PATTERNS IN THE UPPER COLORADO RIVER BASIN

report to

Texas Water Development Board

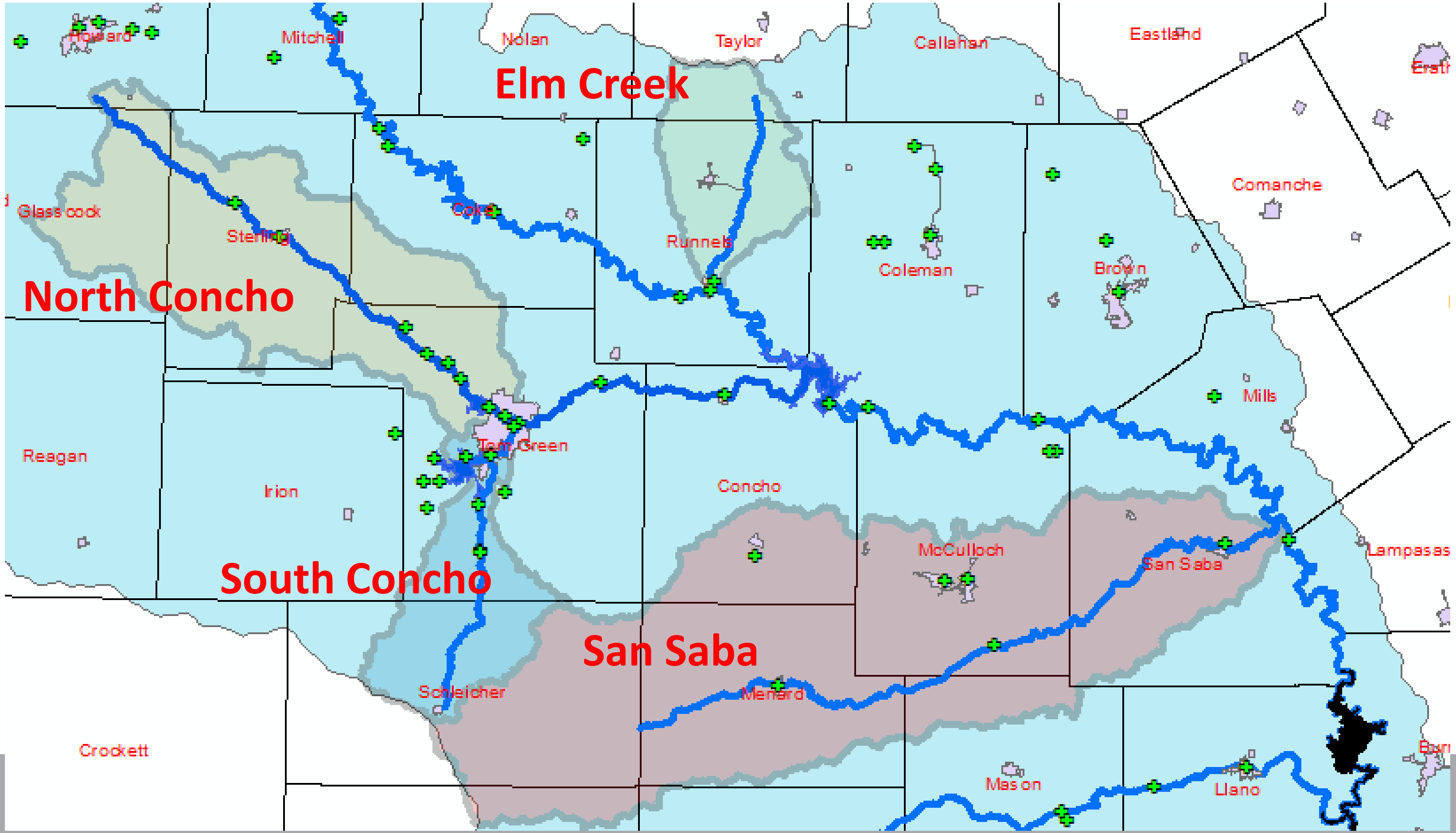
TWDB Contract No. 1600012011

August 2017

Phase II Project Objectives

Project Goal

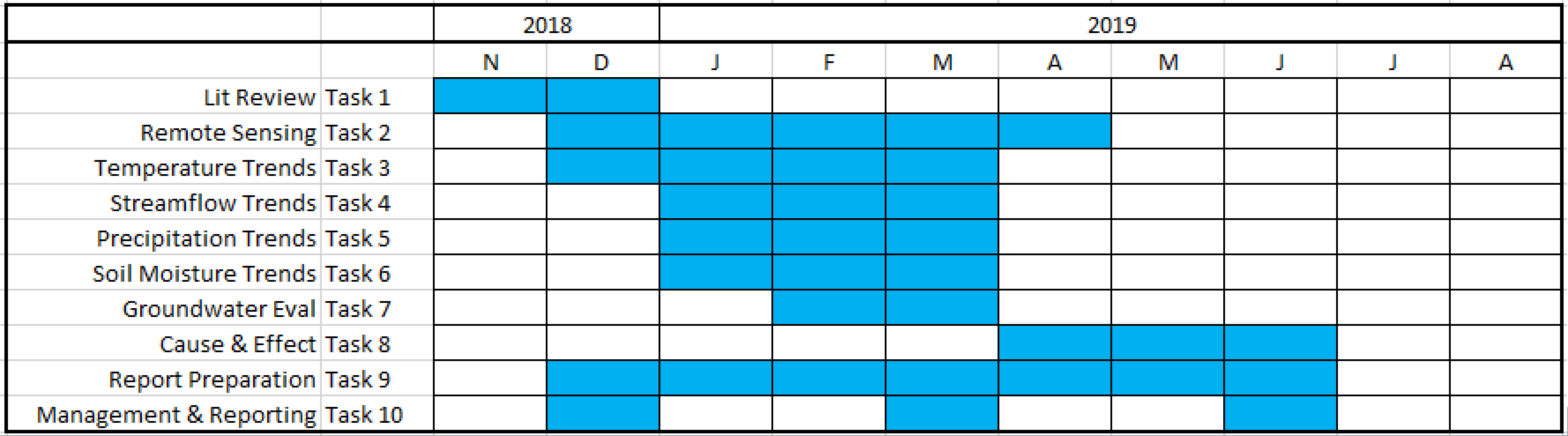
The goal of this project is to demonstrate and quantify the causal factors for observed changes in the rainfall-streamflow response in four regions in the Upper Colorado River Basin upstream of the Highland Lakes.



Phase II Project Schedule

- DRAFT Final Report Due by June 30, 2019
  - TWDB has 30 days to review an provide comments

- Final report due 60 days from June 30, 2019
  - August 29, 2019
  - 30-day review period for acceptance by TWDB



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References Review – Task #1

- Review literature to develop plan
- Phase 1 Report – KRC
- References suggested by TWDB
  - Obtained & Reviewed

References:

- Crooks, S. and Kay, A. (2015). Simulation of River Flow in the Thames Over 120 Years: Evidence of Change in Rainfall-Runoff Response? Journal of Hydrology: Regional Studies 4: 172-195.
- Duan, K., et al. (2017). Future Shift of the Relative Roles of Precipitation and Temperature in Controlling Annual Runoff in the Conterminous United States. Hydrology and Earth System Sciences 21(11): 5517.
- McAfee, S. A., et al. (2017). Application of Synthetic Scenarios to Address Water Resource Concerns: A Management-Guided Case Study from the Upper Colorado River Basin. Climate Services 8: 26-35.
- Woodhouse, C. A., et al. (2016). Increasing Influence of Air Temperature on Upper Colorado River Streamflow. Geophysical Research Letters 43(5): 2174-2181.
- Xia, Y., et al. (2012)(a). Continental-Scale Water and Energy Flux Analysis and Validation for North American Land Data Assimilation System Project Phase 2 (NLDAS-2): 2. Validation of Model-Simulated Streamflow. Journal of Geophysical Research: Atmospheres 117(D3).
- Xia, Y., et al. (2012)(b). Continental-Scale Water and Energy Flux Analysis and Validation for the North American Land Data Assimilation System Project Phase 2 (NLDAS-2): 1. Intercomparison and Application of Model Products. Journal of Geophysical Research: Atmospheres 117(D3).

Task #2 – Remote Sensing Analysis – Power of Google Earth

Conclusions from Part I Report

Noxious Brush

Almost all of the study sites are believed to have some degree of noxious brush problems in their contributing watersheds; however, study sites #1, #2, and #3 have had numerous feasibility studies conducted and published that estimate large quantities of streamflow could be recovered if various levels of brush control were implemented. In particular, the North Concho Brush Control Project was completed in the watershed of study site #1, with approximately 340,000 acres of ash juniper and honey mesquite being removed by about 2011. Many experts disagree about the success of substantially increasing flows on a watershed scale by removing brush, and monitoring information after this project was completed only show small gains in streamflow and groundwater elevations. However, several of the years since the project was completed experienced low rainfall, possibly contributing to the inconclusive results and the feasibility reports for this project indicated that that aquifers in the area would need to recover substantially before the predicted increases in surface water flow would be realized. The acreage of noxious brush that has been removed from this watershed is significant, amounting to approximately 40% of the total watershed area of the North Concho River. Consequently, the question of whether brush control of this magnitude can substantially increase flow on a watershed basis will likely have to be answered in the coming years, as more data become available to facilitate comparison of observed flows before and after this brush control project was implemented.

Small Reservoirs

The results from these analyses and other published information reviewed suggest that the cumulative effects of numerous small reservoirs in the watersheds upstream of the study sites have impacted the observed and naturalized flows to some degree. However, the body of information available to quantify all of these small reservoirs' location, size and date of completion is very limited and is not sufficient to fully address this issue.

Task #2 – Another Perspective on Noxious Brush

Decreased Run-off from a Rancher's Perspective

Stanley Miller and Richard Golladay

July 24, 2018

A 75-year-old rancher named Stanley Miller in Llano County knows exactly what has decreased run-off to the Highland Lakes in recent years. Below are his observations over a lifetime.

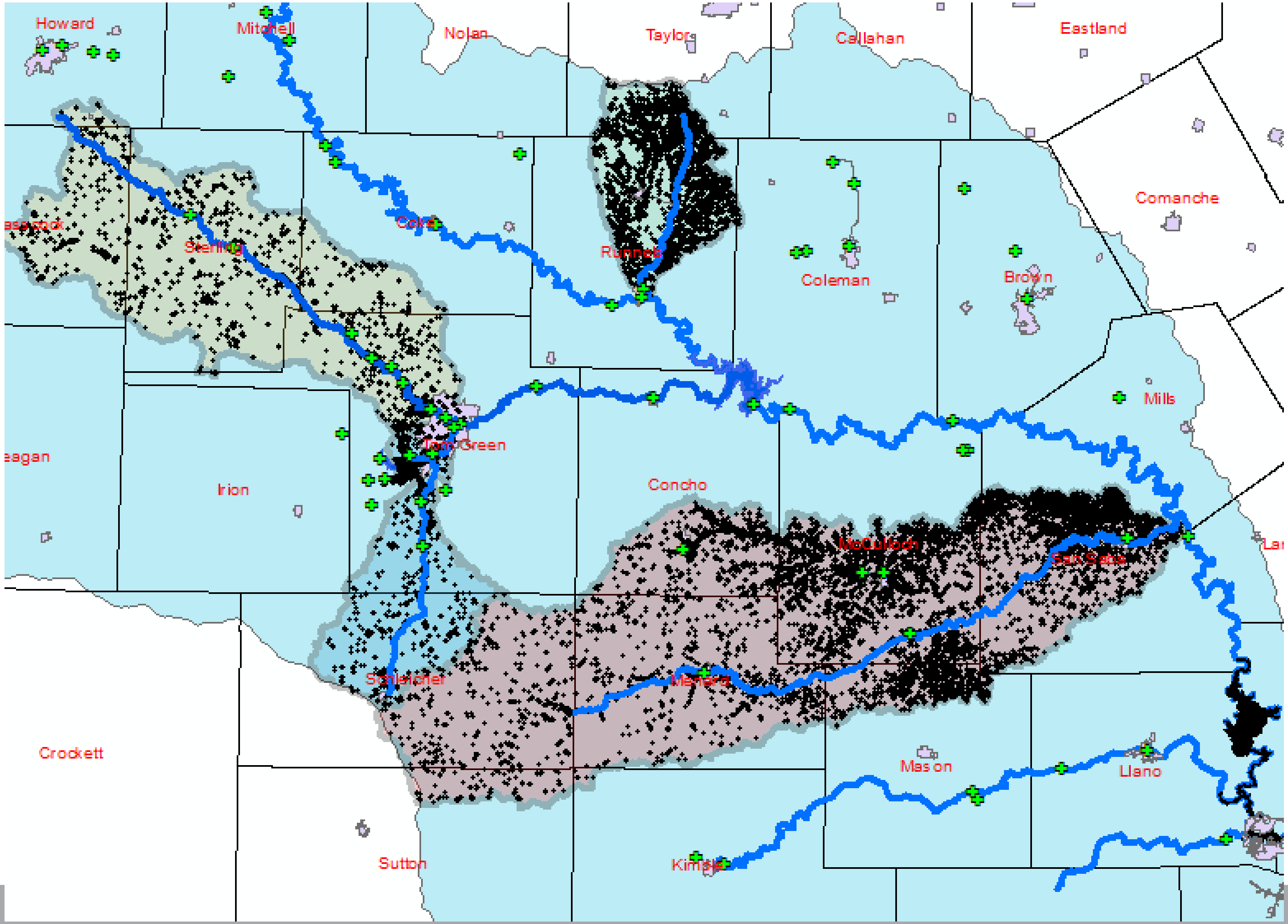
The biggest impact on run-off was return of the coyotes (following the ban of 1080 poison), because it ended the sheep and goat business forever in most of the Hill Country during the decade of the 1980's, except on small tracts of 50 acres or less. Coyotes also eliminated the over-population of rabbits. (Sheep, goats, and rabbits are short grass grazers, so they left the land bare and allowed a lot of run-off when it rained.) Ranchers were forced to switch to raising cattle, almost exclusively.

Also, during the predominantly sheep and goat raising economy (before 1980), ranchers planted small grains or hay grazer. Plowing and laying the fields bare between crops created more erosion (and run-off). "We were carrying rocks out of fields as they were uncovered from the erosion."

Following the shift to a cattle economy, two innovations drastically changed ranching: (1) planting and fertilizing improved perennial grasses in the fields, and (2) rotation grazing of cattle. Rotation grazing, in particular, enabled older native perennial grasses to be re-established on the range land not in fields. Both re-established native grasses on range lands, and improved grasses in fields, drastically reduced run-off and erosion, since it means more year-round ground cover. This transition began in the 1990's.

Elimination of Short Grass Grazers Yields less runoff

Task #2 – Remote Sensing Analysis – Impoundments



11,109 Waterbodies in NHD (Created 2002)

Minimum Area: 0.018 acres
Maximum Area: 6,174 acres

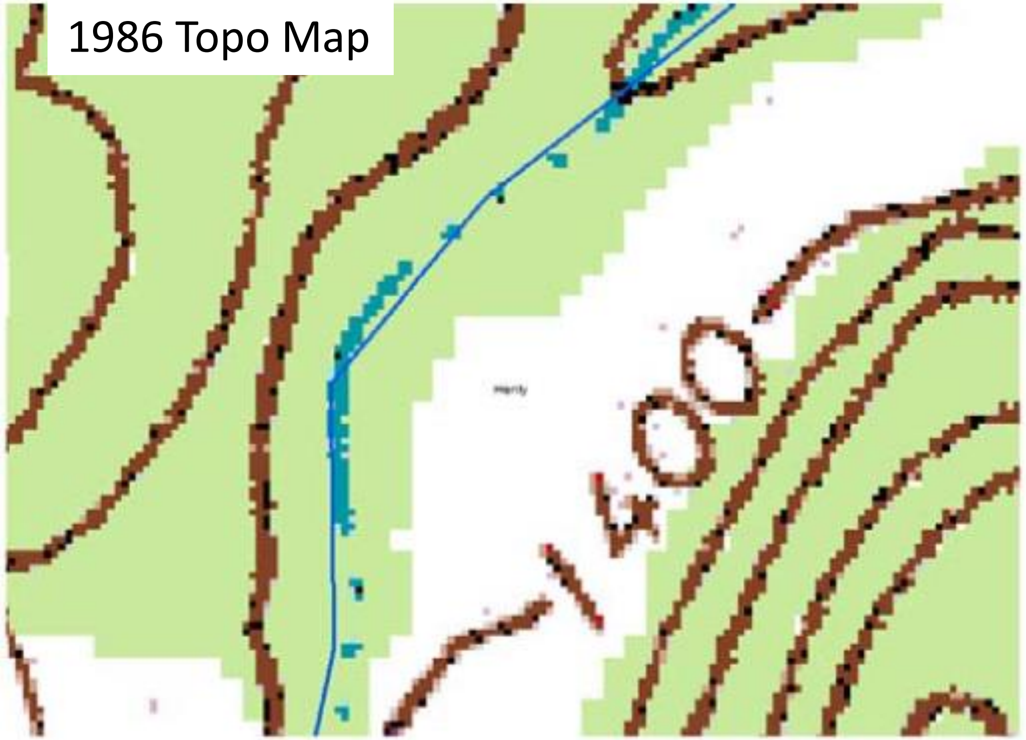
Total Surface Area: **23,188 acres**

Area of Lake Buchanan: *22,137 acres*

In 2017 – Lake Buchanan Lost to Evaporation
38,190 acre-ft = 53 cfs all year long!

Questions:
Are these all the existing ponds?
When were the ponds constructed?

Task #2 – Remote Sensing Analysis



1986 - No Impoundment

2012 Impoundment

Attempt to identify:

- When Ponds were constructed
- Approximate Size and Storage Capacity
- Evaporative Losses & Streamflow Reduction Capacity

Approach:

- NHD – Manual Analysis
- GIS Data from TNRIS
- NID Data (Phase 1)
- Google Earth Engine

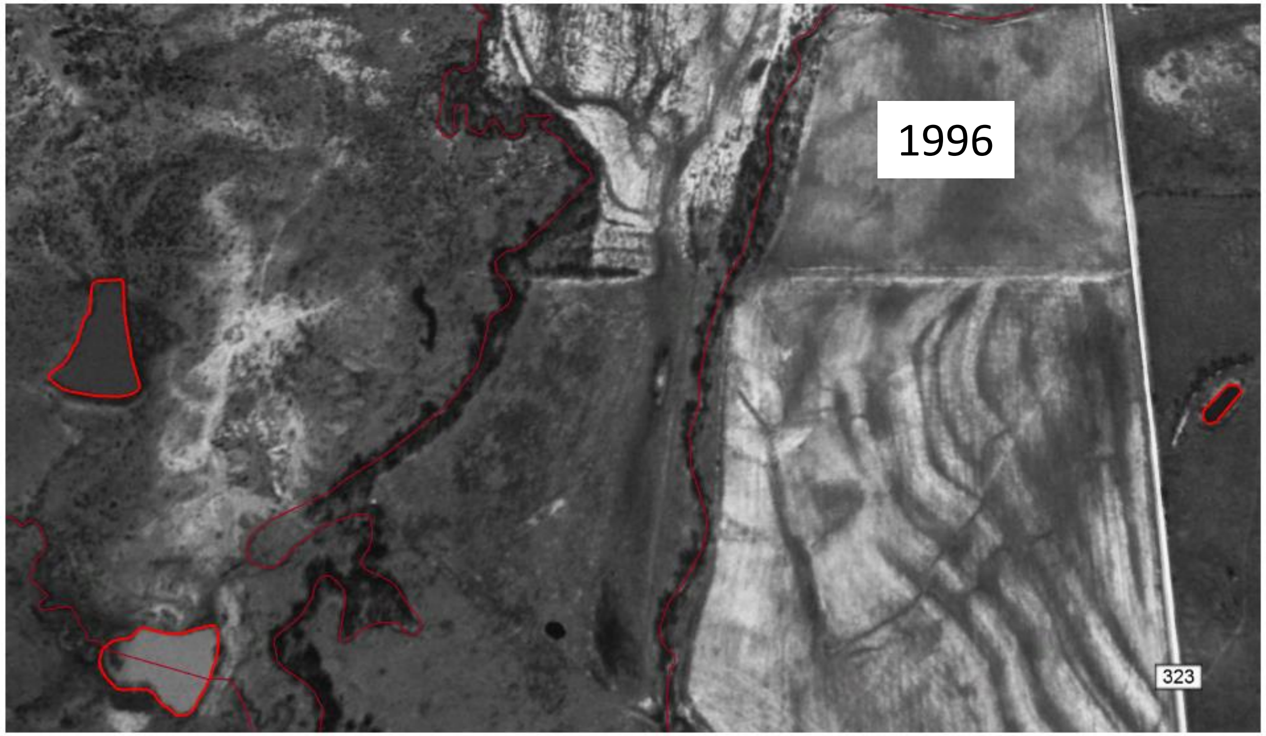
Task #2 – Remote Sensing Analysis – Power of Google Earth

Reservoir Now
Not in NHD!

No Reservoir

Google Earth Engine – Programming to identify Pond Extents
Potential Automatic Processing of Study Area Images
Manual Checks & Comparisons

Task #2 – Remote Sensing Analysis – Elm Creek Watershed Examples



Large Reservoir Constructed between 1996 and 2017.

28 surface acres per image

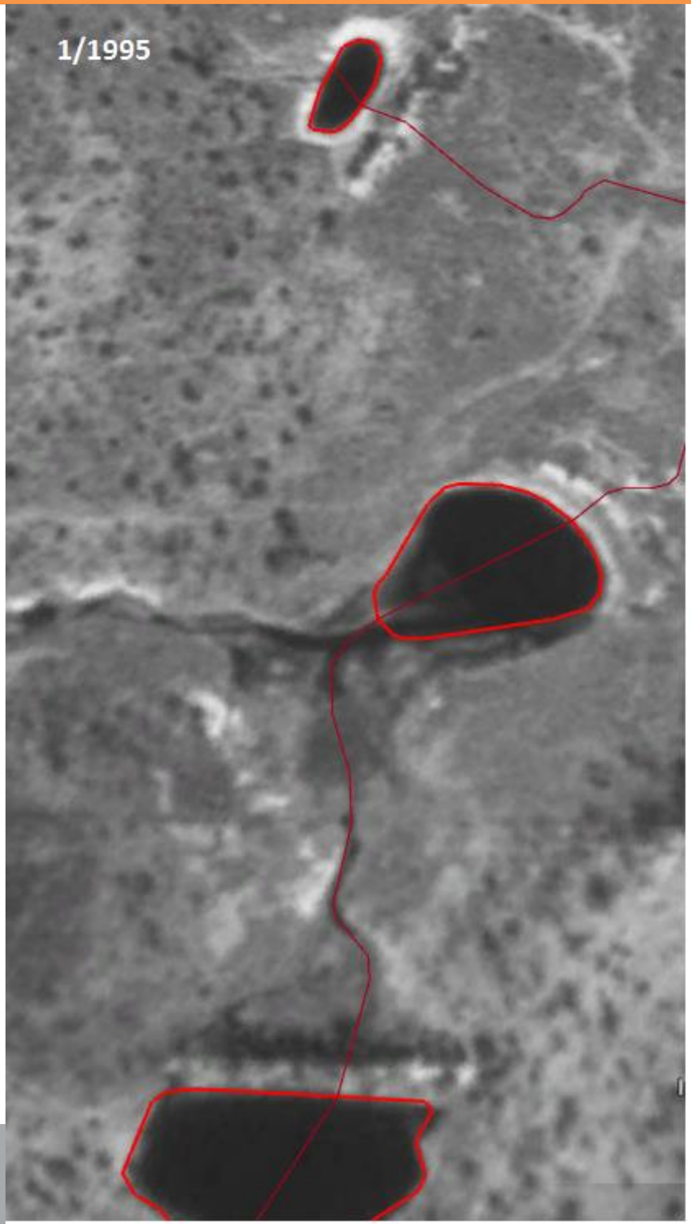
Likely maximum depth greater than 10 ft
Based on 1964 contour map

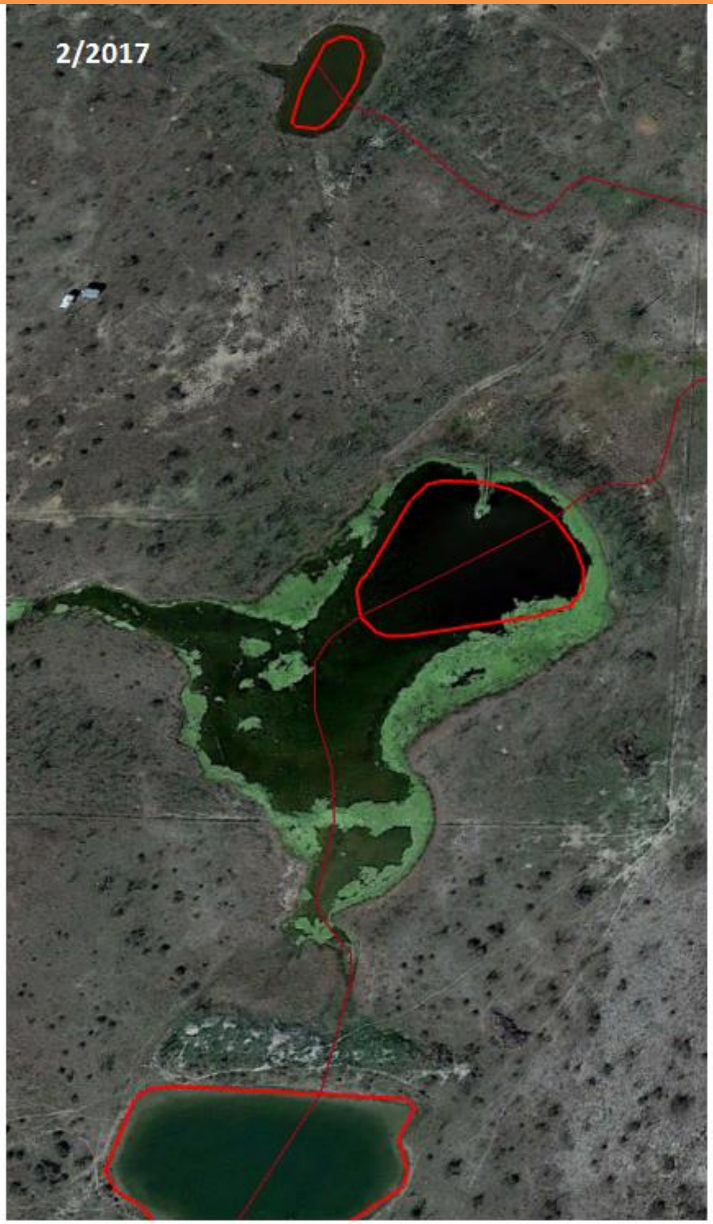
Possibly 100-200 acre-ft storage

Appears to have a low-flow outlet capacity

Possibly within WAM Model?

Task #2 – Remote Sensing Analysis – Elm Creek Watershed Examples





Increased Capacity/Area of Previously Identified Ponds

Could result from high flows in 2016-2017

Demonstrates capacity to store water
In watershed, rather than contribute
To downstream flows in larger creeks, rivers

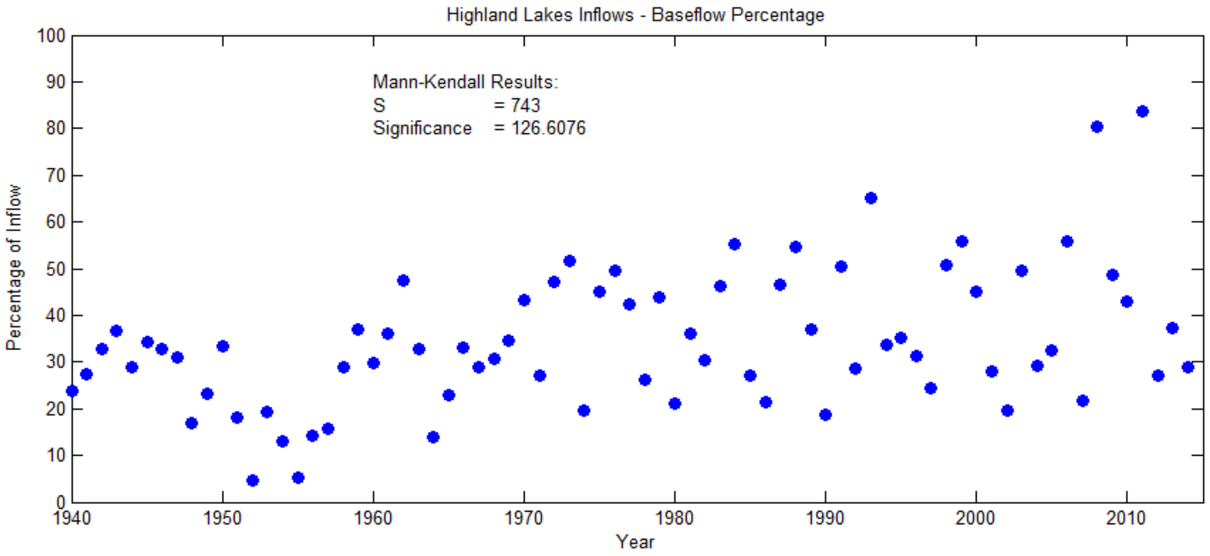
Task #2 – Remote Sensing Analysis – Elm Creek Watershed Examples

Ponds in 2017 Not Included in NHD

Task #3 – Temperature Trend Analysis

- Existing literature relates lower runoff response to higher temperatures
  - Snowmelt areas – so results may not be applicable
- Get Long-term Temperature Records
- Statistical Assessment of Trends
  - Means, minimums, maximums
  - Daily, monthly, seasonal basis
  - # Days over 100 Degrees

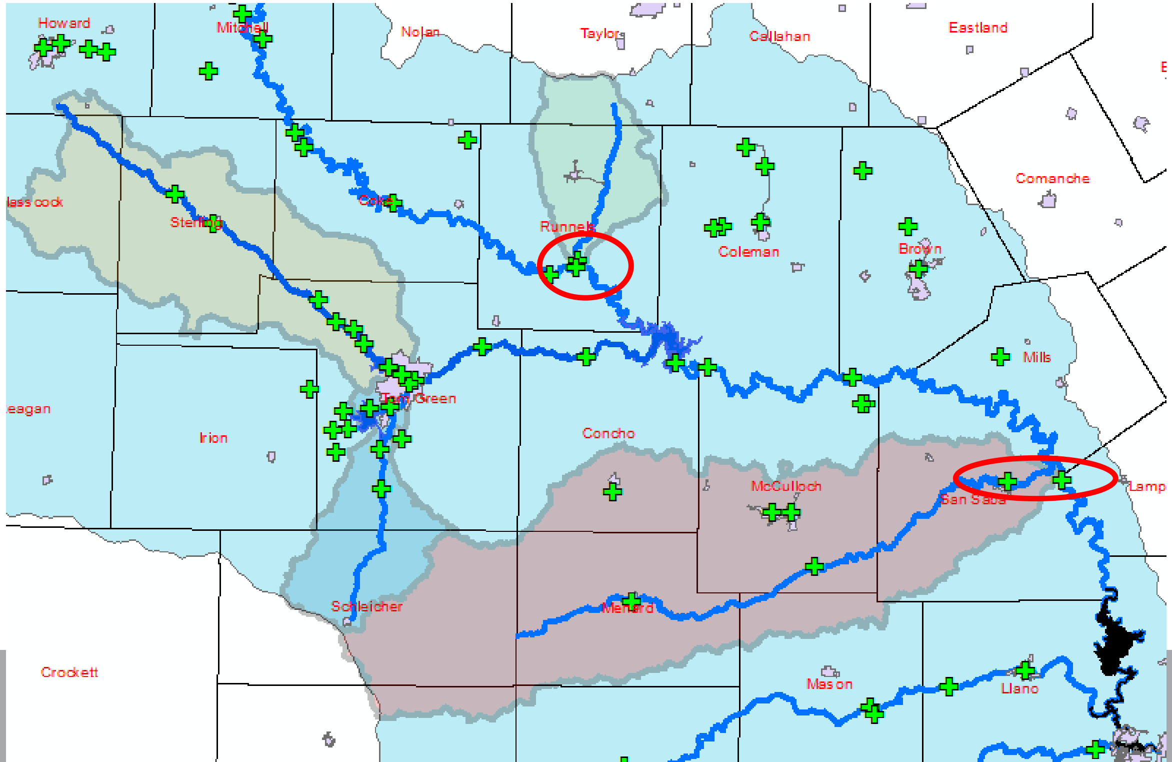
Mann-Kendall Statistical Trend Analysis Example



**Will find and provide references
Can use alternative method if desired
LRE has used Mann-Kendall to assess stationarity in WAM, USGS Streamflow gauges

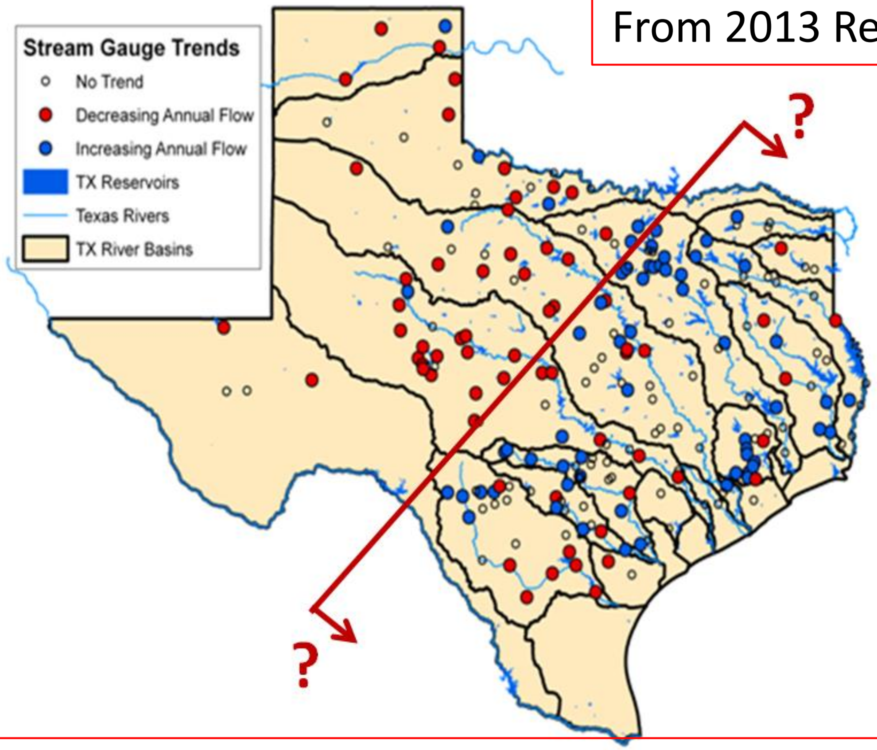
Task #4 – Streamflow Trend Analysis

- Trends on both Gauged and Naturalized Flows
  - Review Phase I Results
- Get Long-term Records - USGS
- Statistical Assessment of Trends
  - Change Points – Possibly using IHA & Mann-Kendall



Mann-Kendall Statistical Trend Analysis
Example

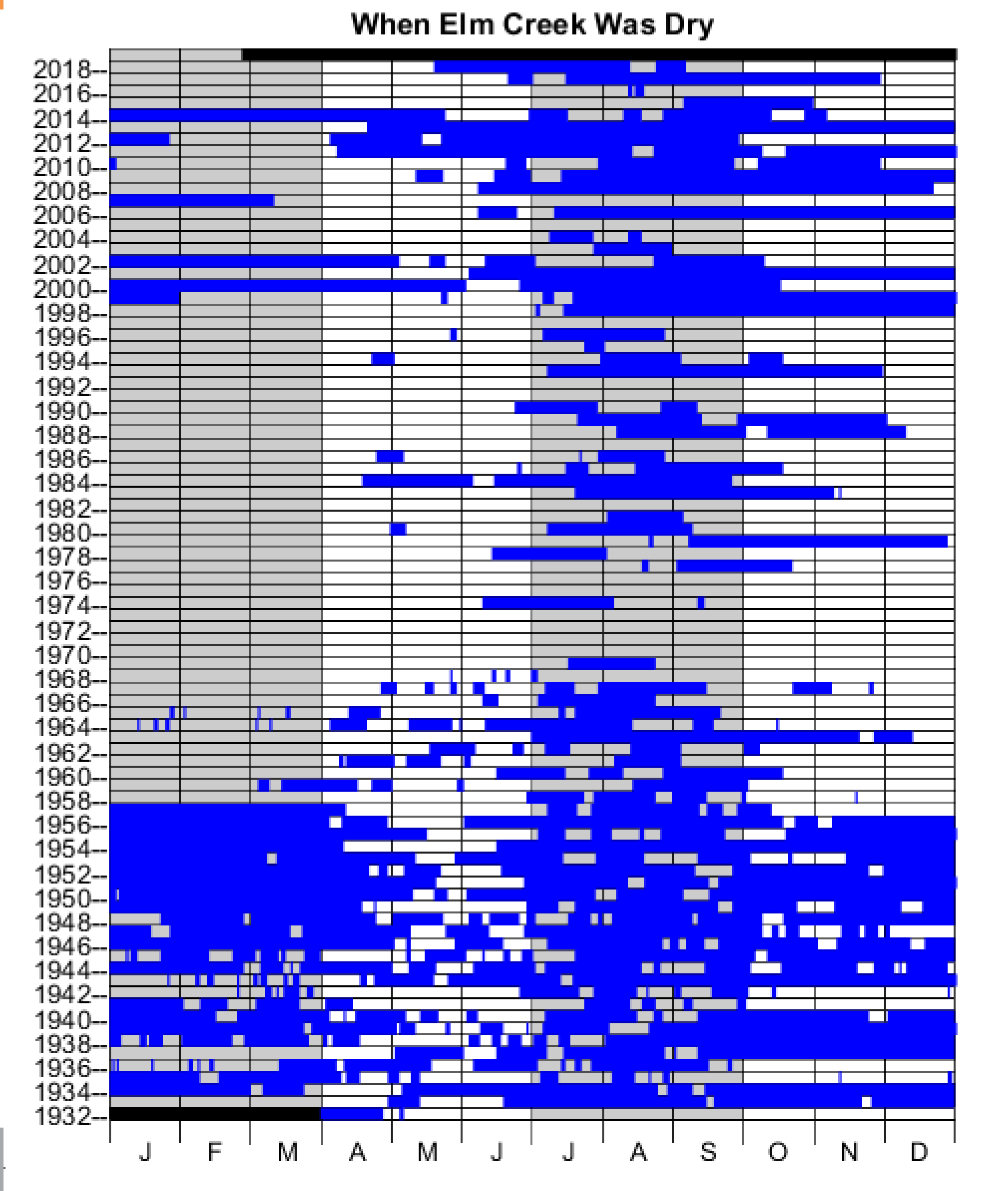
From 2013 Report

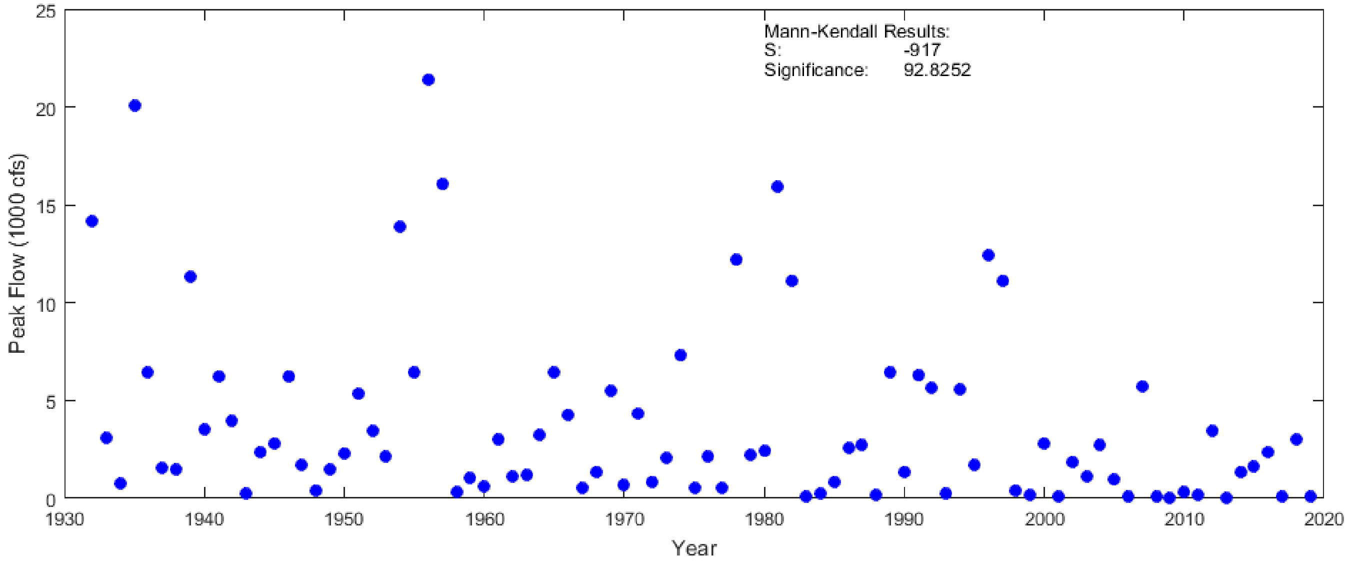


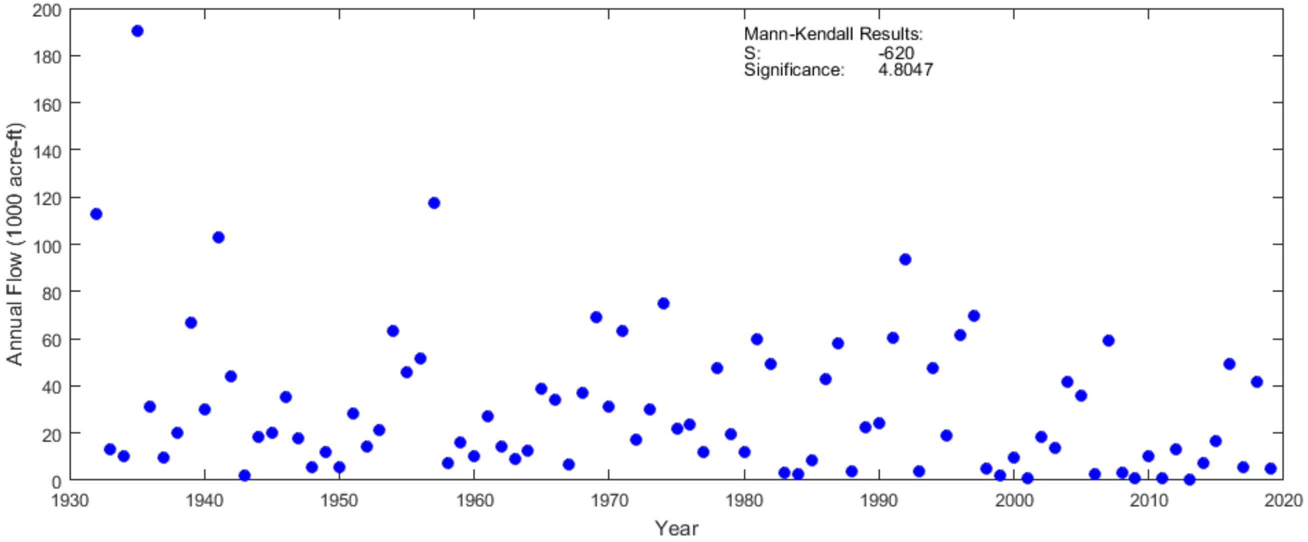
May be worth comparing gauges against drainage area ratios

San Saba & Elm Creek

Task #4 – Streamflow Trend Analysis







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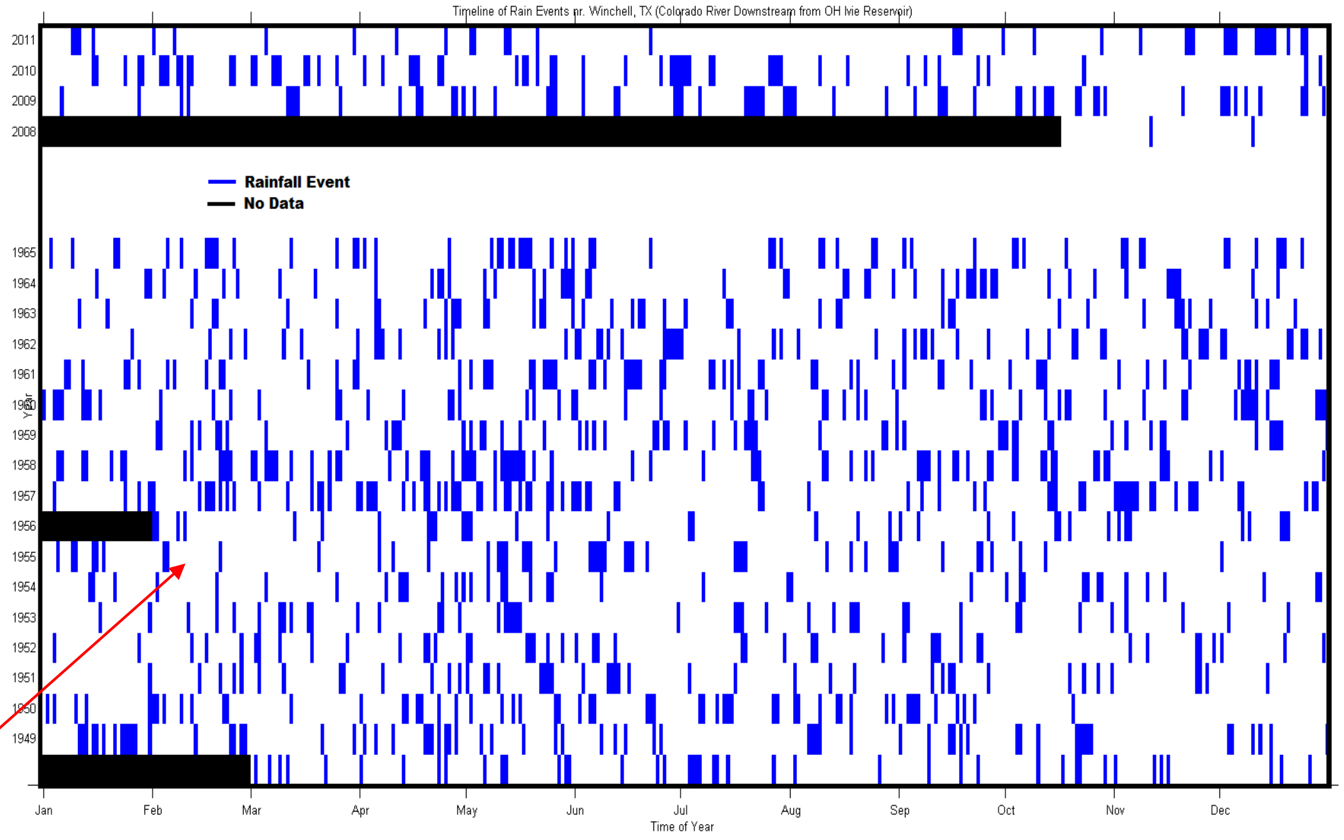
Task 5 – Precipitation Trend Analysis

- Obtain Long-term Precipitation Records
  - 4 subject watersheds
  - Re-use of Phase 1 Data

- Fill in data gaps – using standard methods

- Trend Analysis –
  - 5-day, 10-day, monthly, seasonal (defined?)
  - Dry period duration
  - Date of wet season end?



Some visual trends possible
Need to quantify

Winchell, TX Rainfall – Days of Recorded Rain
1948-1965, 2008-2011

Task #6 – Soil Moisture Data Analysis

- Identify and map soil moisture data stations in study area
  - Unknown at this time how much data is available
  - WeatherAnalytics & other companies make
    Gridded data available. Sources unknown
- Soil moisture
  - Identified as a contributor to Colorado River runoff response
    (Not TX Colorado River)
  - Not conclusive its impact relative to precipitation and temperature

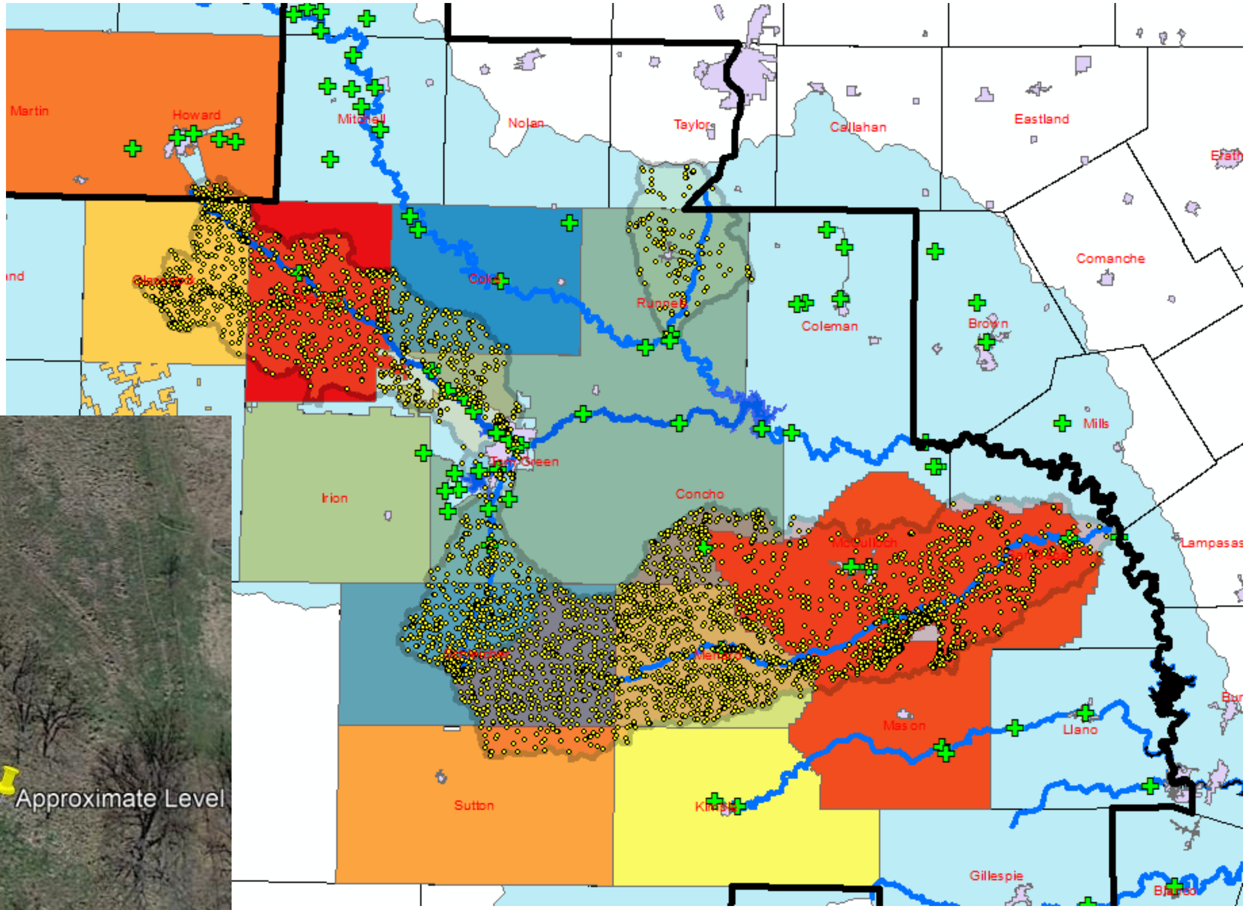
- Potential Water Balance for assessing soil moisture?
  - Rainfall – Net Evaporation – soil storage = runoff
  - Define Timescale (months, weeks)
  - Estimate Net Evaporation (TWDB water surface data, Blainey-Criddle estimates?)

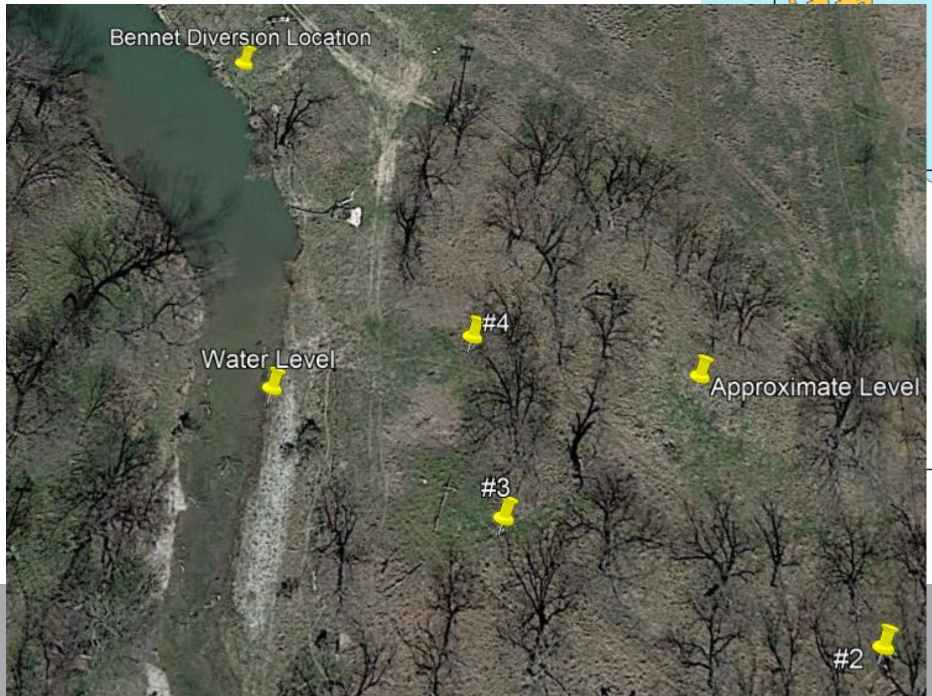
- Ideas to be developed through data acquisition & Review

Task #7 – Groundwater Level Evaluations

- Mapping Study Area well locations
  - Possible 3-D Mapping using Well Depth & Aquifer Formation Info
  - Water Level Maps, Trends
- Compiling historical and permitted pumping quantities
  - GAMs & GCD interaction (11)
- Review of TWDB tributary aquifer report
  - To assess possible streamflow-well interaction
  - San Saba River Focus

4,519 wells in TWDB Groundwater Database – In Study Area





Task 8 – Demonstrating Cause and Effect – RRR

- Methods under consideration and development
  - Everything is connected – but by how much?
  - Other Analyses will lead into this task, suggest approach

- Likely approach – Comparative Water Budgets
  - Simulate a Rainfall event on a watershed
    - Estimate runoff at outlet
    - Considering land use/initial abstractions
    - Considering stormwater ponds/stock tanks
    - Considering temperature/evap/precip changes over time

  - Compare Scenarios & Demonstrate resulting change in streamflow
  - Compare changes to observed changes in streamflow for each watershed

Evaluation of Rainfall-Runoff Trends in the Upper Colorado River Basin
Phase II

Presentation to BBASC

March 1, 2019

QUESTIONS/DISCUSSION

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